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(54) **MULTI-POINT COOLING SYSTEM FOR A SOLAR CONCENTRATOR**

(75) Inventors: **Supratik Guha**, Yorktown Heights, NY (US); **Yves C. Martin**, Yorktown Heights, NY (US); **Robert L. Sandstrom**, Yorktown Heights, NY (US); **Theodore G. van Kessel**, Yorktown Heights, NY (US)

(73) Assignee: **International Business Machines Corporation**, Armonk, NY (US)

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,604,601 A 7/1952 Menzel  
3,070,699 A 12/1962 Lehmann et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CN 101388420 A 3/2009  
DE 2749992 A1 5/1979

(Continued)

OTHER PUBLICATIONS

International Preliminary Report on Patentability for PCT Application No. PCT/US2011/020654, dated Jul. 26, 2012, pp. 1-7.  
Chia-Yen Lee et al., "Sun Tracking Systems: A Review," Sensors 2009, 9, 3875-3890.  
International Search Report; International Application No. PCT/US2011/020654; International Filing Date: Jan. 10, 2011; Date of Mailing: Mar. 9, 2011.

(Continued)

*Primary Examiner* — Kenneth Rinehart

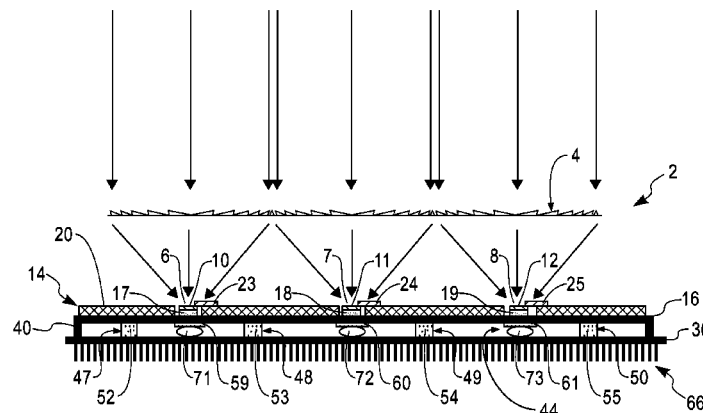
*Assistant Examiner* — Bao D Nguyen

(74) *Attorney, Agent, or Firm* — Cantor Colburn LLP; Vazken Alexanian

(57) **ABSTRACT**

A solar concentrator includes an optical member having a focal point. The optical member is configured and disposed to direct incident solar radiation to the focal point. A support member is positioned adjacent to the focal point of the optical member. A solar energy collector is supported upon the support member. The solar energy collector is positioned at the focal point of the optical member. A base member is positioned in a spaced relationship from the support member. The base member and the support member define a chamber section that is in a heat exchange relationship with the solar energy collector. The chamber section is configured to absorb and dissipate heat from the solar energy collectors.

**9 Claims, 2 Drawing Sheets**



(51)	<b>Int. Cl.</b>			2005/0161581	A1	7/2005	Michiyama et al.
	<b>H01L 31/052</b>		(2014.01)	2006/0041345	A1	2/2006	Metcalf
	<b>H01L 31/054</b>		(2014.01)	2006/0090747	A1	5/2006	Harrington
	<b>F24J 2/52</b>		(2006.01)	2006/0225778	A1	10/2006	Brabec et al.
(56)	<b>References Cited</b>			2006/0243319	A1	11/2006	Kusek et al.
				2007/0033828	A1	2/2007	Hartkop et al.
				2007/0051360	A1	3/2007	Rhee
				2007/0144574	A1	6/2007	Yada
<b>U.S. PATENT DOCUMENTS</b>				2007/0215199	A1	9/2007	Dold et al.
				2007/0272295	A1 *	11/2007	Rubin et al. .... 136/246
3,293,440	A	12/1966	Mueller	2008/0017784	A1	1/2008	Hoot et al.
3,370,293	A	2/1968	Green	2008/0087274	A1	4/2008	Chen
3,866,285	A	2/1975	Clark	2008/0110594	A1 *	5/2008	Martin et al. .... 165/80.4
3,984,685	A	10/1976	Fletcher et al.	2008/0128586	A1	6/2008	Johnson et al.
3,984,686	A	10/1976	Fletcher et al.	2008/0138634	A1	6/2008	Morris et al.
4,027,651	A	6/1977	Robbins, Jr.	2008/0164135	A1	7/2008	Slook
4,045,246	A	8/1977	Malavsky et al.	2008/0172256	A1	7/2008	Yekutiely
4,081,289	A	3/1978	Campbell, III	2008/0245930	A1	10/2008	Nayfeh et al.
4,086,485	A	4/1978	Kaplow et al.	2008/0276929	A1	11/2008	Gerwing et al.
4,107,521	A	8/1978	Winders	2008/0283121	A1	11/2008	Guerra
4,146,785	A	3/1979	Neale	2008/0308152	A1	12/2008	Grip
4,200,472	A	4/1980	Chappell et al.	2008/0314438	A1	12/2008	Tran et al.
4,223,214	A	9/1980	Dorian et al.	2009/0043253	A1	2/2009	Podaima
4,225,781	A	9/1980	Hammons	2009/0056790	A1	3/2009	Tian et al.
4,262,195	A	4/1981	White et al.	2009/0084435	A1	4/2009	Guha et al.
4,278,829	A	7/1981	Powell	2009/0095342	A1	4/2009	Lin et al.
4,320,246	A *	3/1982	Russell .... 136/248	2009/0188488	A1	7/2009	Kraft et al.
RE30,961	E	6/1982	Robbins	2009/0199846	A1	8/2009	Collins et al.
4,432,343	A	2/1984	Riise et al.	2009/0229794	A1	9/2009	Schon
4,586,488	A	5/1986	Noto	2009/0288656	A1	11/2009	Lin
4,592,129	A	6/1986	Legge	2009/0308377	A1	12/2009	Kleinwaechter
4,687,923	A	8/1987	Bauk	2010/0000518	A1	1/2010	Chen et al.
4,691,075	A	9/1987	Murphy	2010/0023138	A1	1/2010	McDonald et al.
4,730,602	A	3/1988	Posnansky et al.	2010/0031991	A1 *	2/2010	Mochizuki et al. .... 136/206
4,794,909	A	1/1989	Eiden	2010/0095955	A1	4/2010	Carrasco Martinez
4,868,379	A	9/1989	West	2010/0101560	A1	4/2010	Olsson et al.
4,909,316	A *	3/1990	Kamei et al. .... 165/104.26	2010/0180886	A1	7/2010	Chang
5,153,778	A	10/1992	Sasian-Alvarado	2010/0192940	A1	8/2010	Yoon
5,483,060	A	1/1996	Sugiura et al.	2010/0218758	A1	9/2010	Guha et al.
5,498,297	A	3/1996	O'Neill et al.	2010/0326427	A1	12/2010	Chen
5,593,544	A	1/1997	Fahlgren et al.	2011/0139145	A1	6/2011	Mackamul
5,593,549	A	1/1997	Stirbl et al.	2013/0233305	A1	9/2013	Guha et al.
6,018,122	A	1/2000	Hibino et al.	<b>FOREIGN PATENT DOCUMENTS</b>			
6,034,319	A	3/2000	Falbel	DE	4116894	A1	11/1992
6,127,620	A	10/2000	Tange et al.	DE	19801213	A1	7/1999
6,337,129	B1	1/2002	Watanabe et al.	EP	0405678	A1	1/1991
6,399,874	B1 *	6/2002	Olah .... 136/259	EP	2105683	A	9/2009
6,465,725	B1	10/2002	Shibata et al.	JP	58018059	A	2/1983
6,583,349	B2	6/2003	Tanaka	JP	5846684	A	3/1983
6,617,506	B2	9/2003	Sasaki	JP	6176848	A	4/1986
6,686,533	B2	2/2004	Baum et al.	JP	62206612	A	9/1987
6,689,949	B2	2/2004	Ortabasi	JP	6479609	A	3/1989
6,696,637	B2	2/2004	Lawheed	JP	1270607	A	10/1989
6,897,423	B2	5/2005	Redler et al.	JP	2291912	A	12/1990
6,901,994	B1 *	6/2005	Jin-Cherng et al. .... 165/104.26	JP	3-256580	A	11/1991
6,992,276	B2	1/2006	Blauvelt et al.	JP	5052702	A	3/1993
7,100,680	B2	9/2006	Dussinger et al.	JP	7334767	A	12/1995
7,109,461	B2	9/2006	Lasich	JP	87619	A	1/1996
7,148,465	B2	12/2006	Blauvelt et al.	JP	8095641	A	4/1996
7,177,140	B2	2/2007	Clarke et al.	JP	8122420	A	5/1996
7,202,457	B2	4/2007	Janus et al.	JP	8321630	A	12/1996
7,208,674	B2	4/2007	Aylaian	JP	11125765	A	5/1999
7,476,832	B2	1/2009	Vendig et al.	JP	2003322418	A	11/2003
7,579,551	B2	8/2009	Van Marion et al.	JP	200664203	A	3/2006
7,709,730	B2	5/2010	Johnson et al.	JP	2008124381	A	5/2008
7,732,918	B2 *	6/2010	Dangelo et al. .... 257/722	WO	2008034423	A2	3/2008
7,847,228	B2	12/2010	Lin	<b>OTHER PUBLICATIONS</b>			
8,119,962	B2	2/2012	Lam	International Search Report—Written Opinion; International Appli- cation No. PCT/US2011/020654; International Filing Date: Jan. 10, 2011; Date of Mailing: Mar. 9, 2011.			
8,129,668	B2	3/2012	Chang et al.				
8,153,944	B2	4/2012	Hines et al.	International Search Report and Written Opinion for PCT Applica- tion No. PCT/US2011/020654, dated Mar. 9, 2011, pp. 1-10.			
8,178,775	B2	5/2012	Taylor, II et al.				
8,188,413	B2	5/2012	Kats et al.	Merriam Webster's Collegiate Dictionary, 10th Edition, 1997, p. 451.			
8,188,414	B2	5/2012	Linke				
8,188,415	B2	5/2012	Kats et al.	* cited by examiner			
2001/0006066	A1	7/2001	Cherney et al.				
2004/0011395	A1	1/2004	Nicoletti et al.				
2004/0216777	A1	11/2004	Pan				
2004/0231660	A1	11/2004	Nakamura				
2005/0103378	A1	5/2005	Pu et al.				

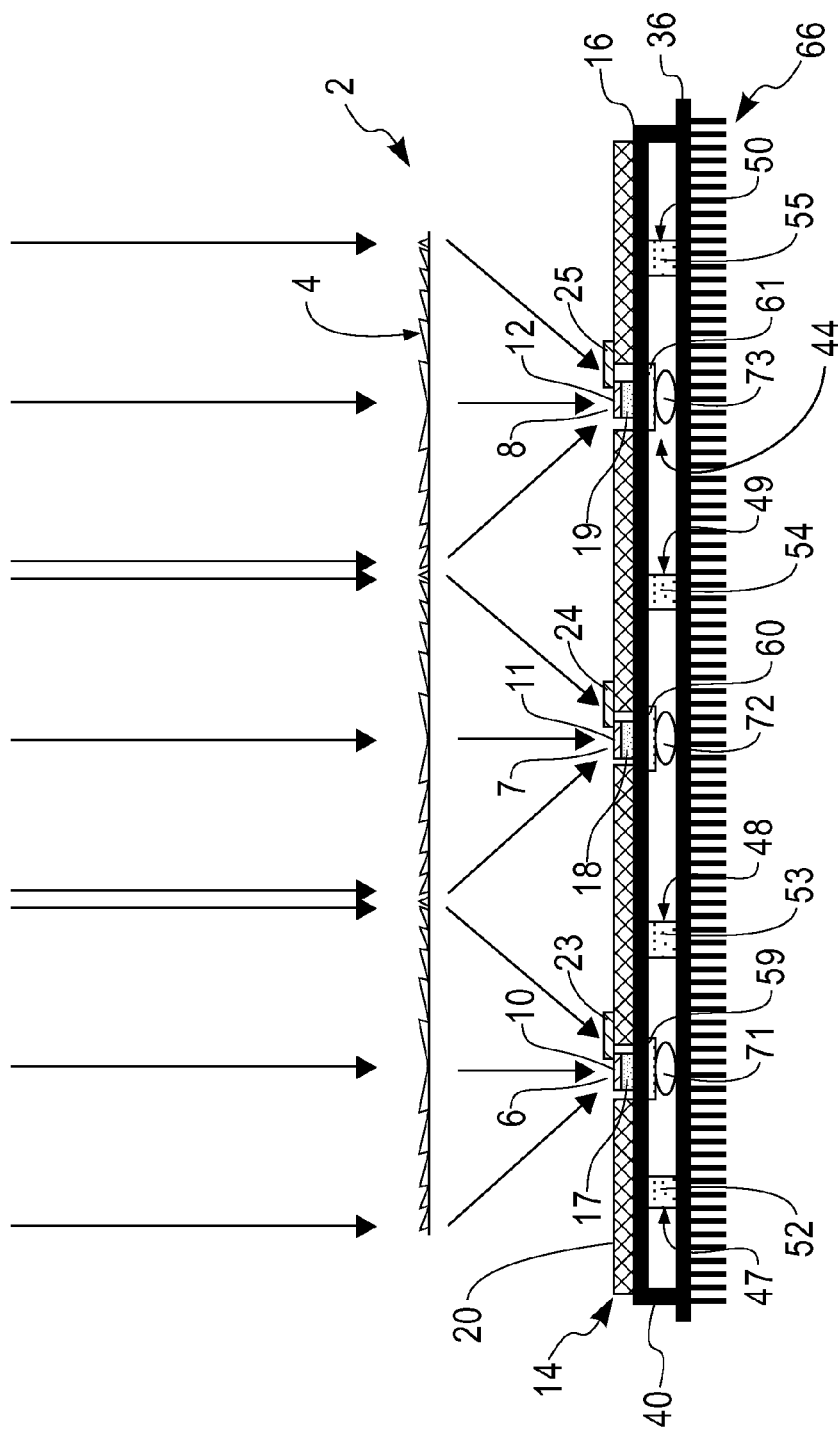


FIG. 1

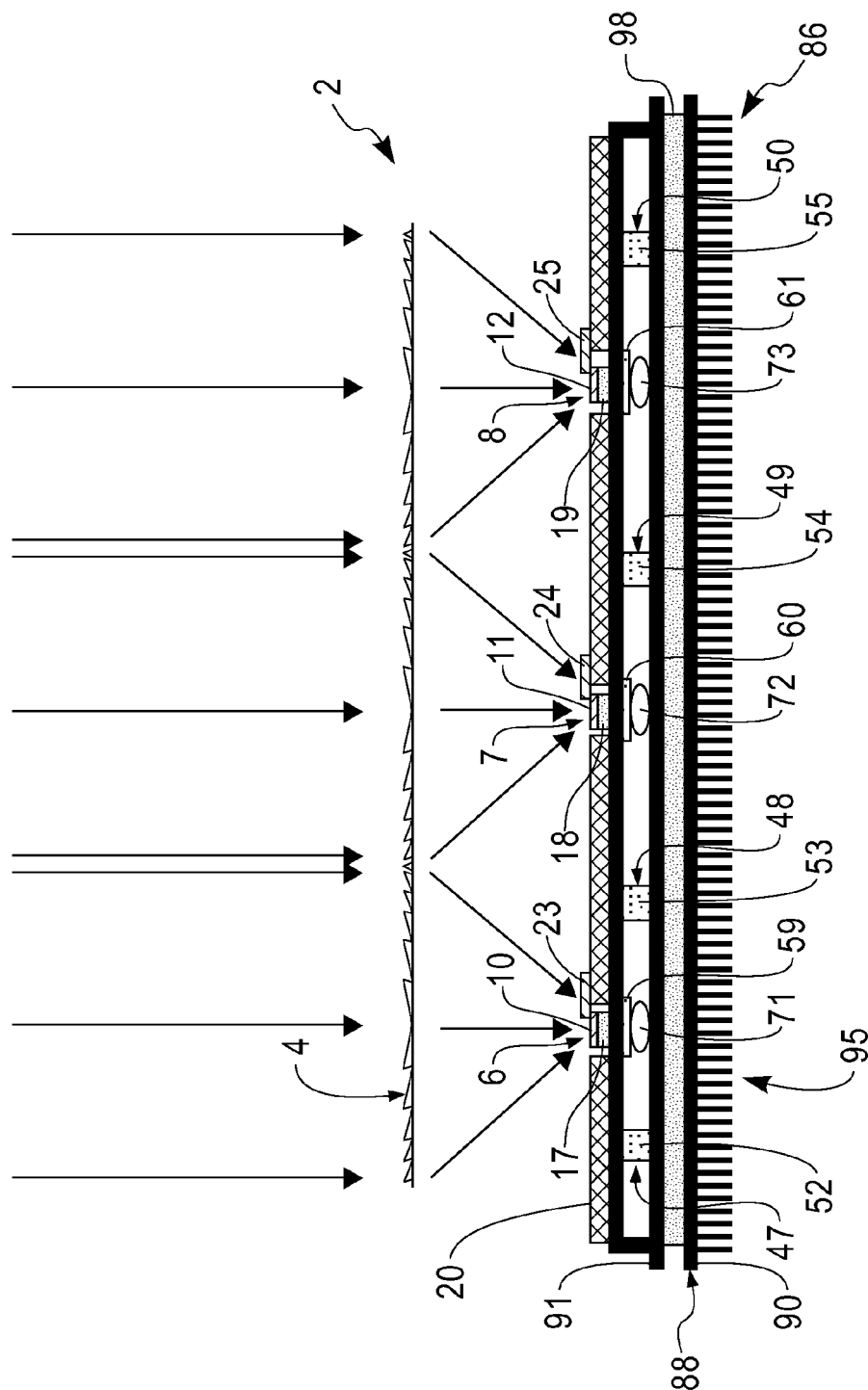


FIG. 2

MULTI-POINT COOLING SYSTEM FOR A  
SOLAR CONCENTRATOR

## BACKGROUND

The present invention relates to solar concentrators, and more specifically, to a multi-point cooling system for a solar concentrator.

Solar power systems fall generally into two categories: fixed position flat panel systems, and tracking concentrator systems. Fixed position flat panel systems employ one or more stationary panels that are arranged in an area having an unobstructed view of the sun. As the earth rotates, the sun's rays move over the stationary panel(s) with varying degrees of intensity depending upon geographic location, time of day and time of the year. In contrast, solar concentrator systems collect, and focus the sun's rays onto one or more solar cells. Certain solar concentration systems employ tracking systems that follow the sun's path in order to enhance energy collection. Simply put, fixed position flat panel systems represent a passive solar collection system, while solar concentrator systems represent a more active energy collection system.

Solar concentrator systems utilizing photovoltaic cells typically operate at or below about 500 suns concentration. Operating at higher sun concentration levels creates cooling challenges. At present, solar concentrator cooling systems are large unwieldy systems and/or possess limited cooling capacity. Thus, one major constraint that limits solar concentrator system is the ability to adequately cool the photovoltaic cells.

## SUMMARY

According to one exemplary embodiment, a solar concentrator includes an optical member having a focal point. The optical member is configured and disposed to direct incident solar radiation to the focal point. A support member is positioned adjacent to the focal point of the optical member. A solar energy collector is supported upon the support member. The solar energy collector is positioned at the focal point of the optical member. A base member is positioned in a spaced relationship from the support member. The base member and the support member define a chamber section that is in a heat exchange relationship with the solar energy collector. The chamber section is configured to absorb and dissipate heat from the solar energy collectors.

Additional features and advantages are realized through the techniques of the present invention. Other embodiments and aspects of the invention are described in detail herein and are considered a part of the claimed invention. For a better understanding of the invention with the advantages and the features, refer to the description and to the drawings.

BRIEF DESCRIPTION OF THE SEVERAL  
VIEWS OF THE DRAWINGS

The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic plan view of a solar concentrator including a multipoint cooling system in accordance with an exemplary embodiment; and

FIG. 2 is a schematic plan view of a solar concentrator including a multipoint cooling system in accordance with another aspect of the exemplary embodiment.

## DETAILED DESCRIPTION

With reference to FIG. 1, a solar concentrator constructed in accordance with an exemplary embodiment is indicated generally at 2. Solar concentrator 2 includes an optical member or lens 4 having a plurality of focal points 6-8. A plurality of solar energy collectors 10-12 are positioned at each of the respective focal points 6-8. With this arrangement, incident solar radiation passing through optical member 4 is guided to focal points 6-8 and, by extension, onto solar energy collectors 10-12. The solar energy collectors 10-12 convert the solar energy into electrical energy. As will be discussed more fully below, solar energy collectors 10-12 take the form of triple junction photovoltaic concentrator cells that operate at high solar concentrations, e.g., concentrations greater than 50 W/cm<sup>2</sup> (about 500 suns). In accordance with one aspect of the exemplary embodiment, solar energy collectors 10-12 can operate at concentrations levels as high as 200 W/cm<sup>2</sup> (about 2000 suns) or more. As such, solar concentrator 2 requires a cooling system that will absorb and dissipate heat generate at solar energy collectors 10-12 operating at such concentration levels. At this point it should be understood that while only three solar energy collectors are shown, solar concentrator 2 could include many more solar energy collectors without departing from the scope of the claims.

In accordance with an exemplary embodiment, solar energy collectors 10-12 are mounted to a multi-point cooling system 14. More specifically, solar energy collectors 10-12 are mounted to a support member 16 formed from a metal or ceramic material having a high heat dissipation co-efficient. In accordance with one aspect of an exemplary embodiment, support member 16 is formed from one or more of Aluminum Nitride (AlN), Aluminum Oxide (Al<sub>2</sub>O<sub>3</sub>), Nickel and Copper. Solar energy collectors 10-12 are mounted to support member 16 via a corresponding plurality of thermal interface members 17-19. In the exemplary embodiment shown, a layer of insulation is mounted to support member 16 about solar energy collectors 10-12. Electrical connections 23-25 extend from respective ones of solar energy collectors 10-12 along insulation layer 20. Electrical connections 23-25 lead to an energy storage device (not shown).

In further accordance with the exemplary embodiment, multi-point cooling system 14 includes a base member 36. Support member 16 is mounted to a base member 36 via a peripheral wall 40. In a manner similar to that described above, base member 36 is formed from a metal or ceramic material having a high heat diffusion co-efficient. Base member 36 is spaced from support member 16 so as to define a chamber section 44. In accordance with one aspect of the invention, chamber section 44 is filled with a vapor formed from, for example, water or ammonia, that enhances heat dissipation from solar energy collectors 10-12. Base member 36 is also coupled to support member 16 via a plurality of structural supports 47-50. Each structural support 47-50 is covered by a wicking material 52-55. In accordance with one aspect of an exemplary embodiment, wicking material 52-55 is formed from sintered copper particles or from a material having machined grooves. Wicking material 52-55 enhances heat transferred from solar energy connector 10-12 into chamber section 44. In order to further enhance heat transfer, a plurality of nucleation membranes 59-61 is mounted to support member 16 within chamber section 44. Each nucleation membrane 59-61 is positioned adjacent a corresponding one of solar energy collectors 10-12. In accordance with an aspect of an exemplary embodiment, nucleation membranes 59-61 are formed from sintered copper particles arranged in a body formed from copper or aluminum. With this arrange-

ment, vapor travels in wicking material **52-55** and or nucleation membranes **59-61**. Heat from the vapor is dissipated through, for example, base member **36** forming a condensate that returns to chamber section **44**.

In order to facilitate heat energy transfer from chamber section **44**, solar concentrator **2** includes a plurality of cooling fins **66** mounted to base member **36**. Cooling fins **66** transfer heat energy from chamber section **44** to be dissipated via air currents passing across base member **36**. In accordance with one aspect of the invention, heat energy dissipation is further enhanced by a plurality of conduits **71-74** extending through chamber section **44**. Conduits **71-74** are configured and disposed to absorb heat energy from chamber section **44**. In accordance with one aspect of the invention of the present embodiment, conduits **71-74** are filled with a liquid that is circulated within chamber section **44**. The liquid absorbs heat energy that is passed to, for example, a cooling medium after which the liquid is re-circulated back to chamber section **44**.

Reference will now be made to FIG. 2, wherein like reference numbers represent corresponding parts in the respective use, in describing another aspect of the exemplary embodiment. In accordance with the embodiment shown, solar concentrator **2** includes a finned cold plate **86** mounted to base member **36**. More specifically, finned cold plate **86** includes a body **88** having a first substantially planar surface **90** and an opposing, second substantially planar surface **91**. First substantially planar surface **90** is provided with a plurality of cooling fins **95** that dissipate heat energy in a manner similar to that described above. Second substantially planar surface **91** is attached to base member **36** via a thermal interface member **98**. Thermal interface member **98** enhances energy transfer from base member **36** to finned cold plate **86**. In accordance with an aspect of an exemplary embodiment, cold plate **86** is formed from one of copper, aluminum or a high heat dissipation coefficient ceramic material.

At this point, it should be understood that the exemplary embodiments provide a system for removing heat energy from a solar concentrator. That is, the present exemplary embodiments enable a solar concentrator to operate above 2000 suns while remaining cool. That is, in contrast to existing systems that must operate substantially below 2000 suns, the exemplary embodiments provide sufficient cooling to enable so the solar concentrator to operate at much higher solar concentration levels in order to enhance energy conversion.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

While the preferred embodiment to the invention had been described, it will be understood that those skilled in the art,

both now and in the future, may make various improvements and enhancements which fall within the scope of the claims which follow. These claims should be construed to maintain the proper protection for the invention first described.

What is claimed is:

1. A solar concentrator comprising:

an optical member having a focal point, the optical member being configured and disposed to direct incident solar radiation to the focal point;

a support member positioned adjacent the focal point of the optical member;

a solar energy collector supported upon the support member, the solar energy collector being positioned at the focal point of the optical member;

a base member positioned in a spaced relationship from the support member, the base member and the support member defining a chamber section that is in a heat exchange relationship with the solar energy collectors, the chamber section being configured to absorb and dissipate heat from the solar energy collectors;

a plurality of conduits extending through the chamber section and directly contacting a surface of the base member in the chamber section, the plurality of conduits absorbing heat from the chamber section received from the solar energy collectors wherein the plurality of conduits transport a heat exchange medium through the chamber section in a heat exchange relationship with a working fluid in the chamber section; and

one or more nucleation membranes arranged between and directly contacting one or more of the plurality of conduits and a surface of the support member in the chamber section, the plurality of conduits being in a heat exchange relationship with the surface of the support member solely through a corresponding one of the one or more nucleation membranes.

2. The solar concentrator according to claim 1, further comprising: a thermal interface member positioned between the solar energy collector and the support member.

3. The solar concentrator according to claim 1, wherein the chamber section comprises a vapor chamber.

4. The solar concentrator according to claim 3, further comprising: a support element extending between the support member and the base member within the chamber section.

5. The solar concentrator according to claim 4, wherein the support element is formed from a wicking material, the support element enhancing thermal energy transfer between the solar energy collector and the chamber section.

6. The solar concentrator according to claim 1, further comprising: a plurality of heat dissipating fins mounted to an external surface of the base member.

7. The solar concentrator according to claim 1, wherein the heat exchange medium is a liquid.

8. The solar concentrator according to claim 1, further comprising: a finned cold plate mounted to the base member.

9. The solar concentrator according to claim 8, further comprising: a thermal interface material positioned between the finned cold plate and the base member.

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